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ABSTRACT

A study examined the role of science texts in classrooms and sought to determine how cognition, attitude/motivation, and socioeconomics affect conceptual change learning from texts in those classrooms. Subjects were students in three high-school science classes, one at each level of instruction: general, regular, and advanced. The classrooms were at a school in a university community located in the southeastern United States, and the instructors were experienced in teaching science. Researchers observed classes and documented classroom procedures in field notes and on videotapes. Results indicated that, although students and teachers rated texts negatively, and texts appeared to be ineffective in bringing about conceptual change, texts did play a central role in instruction. Teachers based lectures and labs on texts, and in some cases, used texts as confirmation of information gained from lectures and labs. Findings suggest that the relevance of physics to career goals might be the most important factor in students' willingness to learn counterintuitive concepts in physics. (Contains 34 references and three tables of data.) (Author/RS)

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ED 374 404

Learning Counterintuitive Physics Concepts

The Effects of Text and Educational Environment

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READING RESEARCH REPORT NO. 16
Spring 1994

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About the National Reading Research Center

The National Reading Research Center (NRRC) is funded by the Office of Educational Research and Improvement of the U.S. Department of Education to conduct research on reading and reading instruction. The NRRC is operated by a consortium of the University of Georgia and the University of Maryland College Park in collaboration with researchers at several institutions nationwide.

The NRRC's mission is to discover and document those conditions in homes, schools, and communities that encourage children to become skilled, enthusiastic, lifelong readers. NRRC researchers are committed to advancing the development of instructional programs sensitive to the cognitive, sociocultural, and motivational factors that affect children's success in reading. NRRC researchers from a variety of disciplines conduct studies with teachers and students from widely diverse cultural and socioeconomic backgrounds in prekindergarten through grade 12 classrooms. Research projects deal with the influence of family and family-school interactions on the development of literacy; the interaction of sociocultural factors and motivation to read; the impact of literature-based reading programs on reading achievement; the effects of reading strategies instruction on comprehension and critical thinking in literature, science, and history; the influence of innovative group participation structures on motivation and learning; the potential of computer technology to enhance literacy; and the development of methods and standards for alternative literacy assessments.

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Cynthia R. Hynd is Associate Professor of Developmental Studies at the University of Georgia and a principal investigator with the National Reading Research Center. She received her doctorate in reading education from the University of Georgia. Her eight years of public school teaching included service as a remedial reading specialist and special education teacher. Dr. Hynd's research focuses on the cognitive aspects of learning from text. Her special interest is how students read textbooks in the sciences and social sciences.

Mary M. McNish is a doctoral student in the School Psychology Program at the University of Georgia. Currently, she is working on an internship at Grady Hospital in Atlanta, Georgia, and is finishing her coursework. She is interested in examining the learning and motivation of students at risk and is currently working on a study of students' feelings of psychological and physical safety in high school.

Gaoyin Qian is Assistant Professor of Reading and Graduate Coordinator at Lehman College of the City University of New York. He received his doctorate in reading education from the University of Georgia. Originally from Shanghai, China, Dr. Qian spent eight years teaching English as a foreign language at Shanghai Institute of Education and East China Normal University. His research investigates how secondary students' motivations and belief systems affect their learning of science concepts from text. He also studies how the different ways of drawing Chinese logographs affects character and word recognition in the learning of Chinese.

Mark Keith taught advanced physics at Clarke Central High School the year of the study. Before becoming a teacher, Mr. Keith received an undergraduate degree in agriculture, worked in environmental education for the Soil Conservation Service, and analyzed oil in a laboratory. He has taught physics and chemistry in two separate schools in nearby counties and was a technical coordinator and system administrator at one of the schools before coming to Clarke Central. He has worked on a master's degree in forest resources with a concentration in hydrology. Presently, Mr. Keith works on a systemwide networking program for the Clarke County Schools. His interests include studying how to present material to students so they can form conceptual frameworks using concept mapping.

Kim Lay is a science teacher at Clarke Central High School who taught physical science to ninth graders in Project Success. She prepared to become a teacher by earning an undergraduate degree in science education. She has taught biology and earth science in addition to physical science. Before coming to her present school, she taught life science to special education students as a subject matter expert in a special program. She is now working on a master's degree in special education with an emphasis in learning disabilities. She believes that her strength in teaching is that she can explain concepts in understandable language.

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Abstract. The authors examined the role of science texts in classrooms and sought to determine how cognition, attitude/motivation, and socioeconomics affect conceptual change learning from texts in those classrooms. Subjects were students in three science classes, one at each level of instruction: general, regular, and advanced. The instructors were experienced in teaching science. Researchers observed classes and documented classroom procedures in field notes and on videotapes. Results showed that, although students and teachers rated texts negatively, and texts appeared to be ineffective in bringing about conceptual change, texts did play a central role in instruction. Teachers based lectures and labs on texts, and in some cases, used texts as confirmation of information gained from lectures and labs. The researchers conclude that the relevance of physics to career goals might be the most important factor in students' willingness to learn counterintuitive concepts in physics.

Concepts in physics often run counter to one's intuitive notions, and when new concepts contradict prior beliefs, they are often rejected (Champagne, Gunstone, & Klopfer, 1985; Nussbaum & Novick, 1982; Maria & MacGinitie, 1981; McCloskey, 1983; Osborne & Freyberg, 1985). Students find it hard to believe, for instance, that gravity pulls objects toward earth at the same constantly accelerating rate, regardless of differing masses. Even advanced students find the concept difficult to

learn because they know that an object with a greater mass will exert a greater force, and they reason erroneously that an object that exerts a greater force must be pulled by gravity at a greater speed than an object that exerts a lesser force. In fact, with concepts related to the motion of objects, students' intuitive notions are remarkably similar to each other, regardless of ability levels. In a previous study, the first author gave the same pretest on projectile motion to students in basic, regular, and advanced classes. Basic students' notions were nearly identical to those of the advanced students.

When teachers rely on regular science lessons to teach counterintuitive concepts, students' intuitive notions seem to persist. Hewson and Hewson (1984) concluded that students handle scientific information in one of four ways. First, if students feel that the information is not counterintuitive, they can *assimilate that information* into existing knowledge structures. This is called conceptual capture. Students with no knowledge or no intuitive notions that contradict the concept to be learned often assimilate new information. However, if the concepts to be learned are counterintuitive, students can *reject the information*, *memorize the information*, or *reconstruct existing knowledge* so that it changes (conceptual exchange). Chinn and Brewer (1993) have provided a more elaborate model. They suggest that when new data conflict with an existing theory (Theory A), people do one of the following: (a) ignore the data; (b) reject the data because of methodological flaws, random error, or alleged fraud; (c) exclude the data from the domain of Theory A by asserting that Theory A is not intended to explain the data; (d) hold the data in abeyance; (e) accept but reinterpret the data to make them consistent with Theory A; (f) accept the data and make minor, peripheral changes to Theory A; and (7) accept the data and change theories, possibly to Theory B. In both the Hewson and Hewson and the Chinn and Brewer models, students have more options for not changing their intuitive ideas than for changing them, which may explain why conceptual change appears to be an elusive outcome of instruction.

Researchers have studied the conditions under which students become convinced to replace non-scientific notions with scientific ones. Posner, Strike, Hewson, and Gertzog (1982) hypothesized that students must become dissatisfied with their nonscientific explanations of phenomena, and the new scientific explanation must be understandable, plausible, and useful. Guzzetti, Snyder, Glass, and Gamas's (1993) meta-analysis of studies conducted by reading researchers and science researchers concluded that successful techniques often included attempts to cause conflict between nonscientific and scientific explanations in an effort to elicit dissatisfaction with the nonscientific ideas. Indeed, research supports the notion that students learn counterintuitive concepts when they are encouraged to examine the difference between prior notions and scientific ones, when they are helped to make bridges between common experiences that demonstrate scientific principles and more complex experiences (Brown & Clement, 1987), and when they are encouraged to consider the plausibility and usefulness of scientific concepts. Reading educators have reported the effectiveness of refutational texts, that is, texts that refute

common sense (but nonscientific) ideas and explain the plausibility and usefulness of scientific ideas (Hynd & Alvermann, 1989; Hynd, Alvermann, & Qian, 1993; Hynd, McWhorter, Phares & Suttles, in press).

The studies from which these conclusions were derived, however, were generally conducted under laboratory conditions (Guzzetti, Snyder, Glass, & Gamas, 1993). Even studies that were more qualitative in nature relied on one-time interviews or tapped students' thinking with regard to artificially posed situations. Researchers have called for more in-depth and ecologically valid classroom research regarding students' counterintuitive notions as well as the conditions necessary for conceptual change to take place (Pintrich, Marx, & Boyle, 1993). They have also called for a consideration of attitudinal, motivational, and sociocultural factors and their contribution to the learning of counterintuitive concepts (Strike & Posner, 1990; Pintrich, Marx, & Boyle, 1993).

In classrooms, the relationships between students and other students and between teachers and students are important considerations in determining what is learned in a curriculum (Blumenfeld, Soloway, Marx, Krajcik, Guzdial, & Palincsar, 1991: Palincsar & Brown, 1984; Resnick, Levine, & Teasley, 1991). Students may have social goals that impede learning goals, or students may have ego-involved goals that reflect extrinsic motivation (e.g., the need for good grades) rather than learning goals (e.g., understanding) that reflect intrinsic motivation. Ego-involved goals seem to lead to less engagement with educational tasks.

Lee (1991) demonstrated that motivational behavior encountered in the science classroom could be placed into six categories: a student who is intrinsically motivated to learn science (pattern 1) has adopted learning goals as a result of keen interest in scientific topics and will complete tasks with a high degree of involvement because of this interest. People who are motivated to learn science (pattern 2) may be partially uninterested, but still persist in tasks, possibly as a result of at least some level of extrinsic motivation. They still wish to understand concepts rather than merely complete tasks, but may be doing so because understanding leads to better grades. People who are intrinsically but inconsistently motivated (pattern 3) will adopt learning goals when they are interested in a topic, but may not try when interest is not there. Students exhibiting pattern 4 are not motivated by learning goals but by ego-involved goals (extrinsic motivation) such as getting good grades. Therefore, they will complete tasks but do not try to truly understand the material. Students exhibiting pattern 5 have neither intrinsic nor extrinsic motivation; therefore, they avoid tasks. In pattern 6, students not only avoid tasks but disrupt task completion by others.

Besides cognitive and motivational factors, sociocultural orientations such as socioeconomic class may affect the acceptance of scientific notions. Although the effect of cultural/racial differences between teachers and students has not been studied in science classrooms, its effect has been noted by educational anthropologists. Wolcott (1987), for instance, found that the native Alaskan students he taught failed to see the relevance of education in their community. As a result, they attempted to engage in simple rote tasks and resisted tasks that would challenge them or lead to any real learning.

McDermott (1987) discussed the effects of education on students from lower socioeconomic classes who are inadvertently viewed as pariahs by teachers as well as by other students. He said that children from lower-class cultures, because of the differences between them and their hosts (teachers) often adapt rationally to the politics of everyday life in the classrooms by becoming school failures and delinquents.

The effect of socioeconomic class may be more pronounced in science classrooms than in social science and other classrooms, especially if tracking systems are evident that mirror socioeconomic divisions. Raudenbush, Rowan, and Cheong (1993) found that higher order thinking skills were emphasized less by teachers who taught math and science in middle and lower tracks than by teachers who taught those disciplines in advanced tracks. One reason, they theorize, is that math and science are fields that not everyone can enter, and limiting expectations for higher order thinking to advanced students may serve a gatekeeping function.

The present study was designed to illuminate the relation between counterintuitive notions and the role of texts in science classrooms, and to help us understand why some students relinquish their intuitive notions in favor of scientific ones and others do not. To address these issues, we examined the role of various cognitive, motivational, and socioeconomic factors made evident through tracking. Our research questions were as follows: (a) What role do texts play in science classrooms? and (b) How do cognition, attitude/motivation, and socioeconomics affect conceptual change learning from texts in these classrooms? As a result of the findings of this study, we hope to plan valid interventions for use in future studies that will help students learn counterintuitive concepts. We felt it was important to chronicle examples of current instruction and learning, however, before we designed those interventions. In this study, no intervention was planned. Rather, students were observed as they proceeded through the regular curriculum, guided by their regularly assigned teachers.

METHOD

Participants

Students. The study took place in three classrooms at a school in a university community with approximately 50,000 residents located in the southeastern United States. The school enrolled more than 5,000 students, 52% of whom were male and 48% female, with a racial make-up of approximately 53% African American, 44% White, and 3% students from other racial groups. The Illinois Test of Basic Skills scores for this high school and the scores of students from a school with a similar make-up in the same community placed students in the 57th percentile. The principal of the targeted school had a good reputation as an administrator. He encouraged independence and creativity among teachers and students, was supportive of research efforts, praised teachers who provided constructive environments for learning, and took an interest in the achievements and problems of individual students.

Students in this high school had been advised to take academic classes in one of three

levels: advanced, regular, and general. Advanced classes were considered to be college preparatory. Regular classes could count as preparation for college, but students who took them were either unsure of their ability to do well in an advanced course or were unsure of their motivation for attending college. General classes did not count as preparation for college. Although students were advised to take courses in one of the three tracks and were placed in these courses according to test scores and the recommendations of teachers, the students could choose to enroll in classes in other tracks if they desired.

The three classrooms visited in this study represented the three levels of science instruction: advanced, regular, and general. The first classroom was an advanced physics class composed of 4 eleventh- and 22 twelfth-grade students who were actively preparing for college work. Eleven of the 26 students had been classified as gifted by the school district, and no student was receiving special education services. These students had previously taken an advanced physical science class in the ninth grade. By the end of the year, three of the 26 students had been accepted and were planning to attend Ivy League schools (Princeton, Harvard, and Columbia), and all other seniors had been accepted and were planning to attend other universities. Although five students did not know what their career plans were, the others were planning careers in medicine, marine science, biology, biochemistry, engineering, architecture, city planning, and computer technology. All planned to major in science or take a number of science courses while in college. Attendance in class was high, with approximately 96% of the students in class each day. The average number of absences per student was 3.3 per semester. Behavior in class was perceived by the teacher as being appropriate. By the end of the study, no formal disciplinary measures had been taken against any of the students. No student was on free or reduced-cost lunch; students were middle-class and above. Of the 26 students, six were African American, one was Asian, one was Portuguese, and another was an exchange student from Venezuela. All others were White Americans. There were 14 males and 12 females. Of the 17 students for whom information was available, four had at least one parent with a doctoral degree, and five had at least one parent with only a high school education. No student, however, had a parent without a high school diploma and only one student lived in a one-parent family.

The second classroom, a general physical science class, was for basic level students and was taught by the same teacher as the advanced physics class. It was composed of 22 students, 9 females and 12 males: 18 were African American and three were White. Seven of the students were receiving special education services (including all three of the White students). Thirteen were in the ninth grade and eight were in the tenth grade. However, most of the tenth-grade students were repeating their ninth-grade year and had taken physical science previously. During the study, four students withdrew from school, one moved to an alternative school, one transferred to another class, and five transferred into the class, leaving 21 students (albeit different ones). Because of poor attendance, only 11 students received

credit for the course by the end of the first semester. Approximately 14 students attended class each day (67%), with students averaging 29 absences each per semester. The teacher thought discipline was a problem. He had sent 12 students to in-house suspension and had taken 70 formal disciplinary actions against students by the end of the study. Nineteen of the 21 students were on free or reduced-cost lunch (90.5%), a reflection of their lower socioeconomic status. For the 12 students for whom information was available, nine were not living with parents or were living in single-parent families. Six of the students had at least one parent who had not graduated from high school, and two students had at least one parent who had attended some college. Of these 12 students, six expressed an interest in attending college, two wished to join the armed forces, two wanted to attend technical school, one had no plans after graduation, and another wanted to begin working in auto-body repair.

The third classroom was a regular physical science class, composed of 15 African American students. These students were taught by another teacher and were part of Project Success, a program aimed at helping students with potential who had been identified in middle school as being at risk for failure in high school because of factors such as poor grades and poor attendance. The teachers in this program discussed students' progress and kept track of variables such as attendance and homework completion. Students participated in classes where they learned clerical skills such as keyboarding and word processing, and life skills such as balancing a checkbook and making career choices. Students in this class had fewer formal disciplinary actions taken against them than the students in the general class: three students received formal disciplinary action for a total of 14 times. However, teacher preference probably accounted for the difference. Researchers' observations of classroom behavior revealed more disruptions than in the general level class, and the teacher confided that the students receiving disciplinary action were a continual problem.

The average number of absences per student was two per quarter at the time of the study, and the class had an average daily attendance of 14 students (93%). No students were receiving special education services, and 12 of the 15 students were receiving credit for the course. Of the 11 students for whom data were gathered, seven were not living with their parents or were living in single-parent homes. Four of the students reported that at least one parent had not completed high school, and another four were not aware of the education of at least one parent. Three students reported that at least one parent had been to college. As for their plans after high school, seven of the 11 reported wanting to attend college, two wanted to attend technical school, one stated no preference, and one reported not wanting to continue education after high school. Their career choices included football, cosmetology, photography, business, law, singing, electrical engineering, fashion design, construction, and being "on the streets."

Teachers. The two teachers whose students participated in the study were in their first year of teaching at the high school where the study took place, but each had considerable experience teaching science at other locations. Mark

taught both the advanced physics course and the general physical science class. Before becoming a teacher, Mark received an undergraduate degree in agriculture, worked in environmental education for the Soil Conservation Service, and analyzed oil in a laboratory. He had taught physics and chemistry at two other schools in nearby counties and had been a technical coordinator and system administrator at one of them. He left teaching to spend a year working on a master's degree in forest resources with a concentration in hydrology, and learned so much math that he became more like a working scientist. Having learned his field better, he felt he could be a better teacher, so he went back to teaching.

To Mark, the important thing about teaching is to present material that students can assimilate into a conceptual framework. He believes material should be presented carefully so that it is part of a logical whole and fits this framework. He uses concept mapping to remind students periodically of the big picture. For example, at the beginning of the year in the advanced physics class, he writes down topics such as force, acceleration, energy, mass, and the like in map form along one wall of his room on a long bulletin board. He draws lines between the related concepts. As he teaches new topics, he adds them to the map, explaining how they are related to the concepts his students have already studied.

Mark also likes to take the individual into account, and tries to create situations in which he can give individual help. He likes for students to be able to think on their own and to know that there are different ways to answer scientific questions and solve problems. He would like his students to be less concerned with grades and more concerned with learning, so he lets students work together, even on tests, and has flexible grading policies. As for his general physical science students, he believes they all have the potential to be learners, but they do not think of themselves as learners. He believes that making the class more informal will allow students who would otherwise resist learning to become interested in scientific topics. Consequently, he sometimes has students work together in groups and talks informally to groups rather than to the entire class.

Kim, the teacher in the regular physical science class, prepared to become a teacher by earning an undergraduate degree in science education. She taught for five years in another state; courses included general biology, basic earth science, basic biology, and regular earth science. Before coming to her present school, she also taught life science to special education students as a subject matter expert in a special program, and worked toward a master's degree in science education. When she moved to her present position, she began working on a master's degree in special education with an emphasis in learning disabilities. She believes that her strength in teaching is that she can say the same thing 12 different ways and she likes planning and having students participate in activities. Like Mark, she encourages her students to look at things from different viewpoints, to pick up thinking skills, and to know that, in science, sometimes there is not just one right answer.

Both teachers, then, were experienced and committed, and believed that part of teaching science was to teach scientific thinking. Both

believed in having students conduct labs and engage in scientific activity, and both were concerned with their students' motivation to learn scientific concepts.

Data Sources and Procedures

Quantitative procedures. Because the study was designed to be observational and descriptive, several data sources were used. Students were tested before and after instruction on four topics related to the motion of objects: balanced forces, friction, gravity, and projectile motion. The test items were read to the basic and regular classes, but advanced students were allowed to take the tests without the researcher reading the items to them. For each topic, there were three tests: a 20-21 item true-false test, a short-answer test, and an application task. The tests on gravity were adapted from similar tests used by Swafford (1989), and the projectile motion tests had been used previously by the first author in other studies (e.g., Hynd, McWhorter, Phares, & Suttles, in press). Before their use, all of the tests were reviewed by the teachers of the classes involved in the study, and changes were made based on their recommendations.

We calculated internal consistency coefficients for the true-false tests using the pretests for the entire sample of students involved in the study. The Cronbach alpha coefficients for the true-false tests were .81 (Balanced Forces), .01 (Friction), -.54 (Gravity) and .79 (Projectile Motion). Not only was there a lack of internal consistency on the Friction test, when we calculated test-retest reliability, we found that it was only .53. Further, interviews with students about their knowledge of friction did not reveal any particularly striking intuitive notions. Therefore, we did not follow students' changes in ideas about friction, and the results of the pre-post Friction test should be viewed with caution.

The Gravity test's internal consistency coefficient was negative. However, when we interviewed students about their conceptions of gravity, we found evidence of nonscientific conceptions across levels, with a large number of students still maintaining their intuitive notions after instruction. Therefore, on the Gravity test, items were omitted until the internal consistency coefficient reached .78, leaving an 11-item test. These 11 items were used in analyses. (These tests are available from the authors.)

Students were also asked to complete an epistemology questionnaire (Schommer, 1990) and an attitude questionnaire (Brekelmans, Wubbles, & Creton, 1990) prior to instruction. On the epistemology measure, three factors were used. These factors had been identified previously by Qian (1993) in a factor analytic study of Schommer's measure using more than 300 students at a nearby high school. The factors were Simple Knowledge, Quick Learning, and Certain Knowledge. A belief in simple knowledge would mean a belief that knowledge consists of isolated facts, rather than complex interwoven conceptual sets. A belief in quick learning would signal a belief that good students are quick learners who do not have to use strategies to help them learn. A belief in certain knowledge would signal a belief that knowledge is a representation of unchanging reality rather than a representation of ideas that

would change with new knowledge. Internal consistency alpha coefficients were: Quick Learning = .79; Simple Knowledge = .65; Certain Knowledge = .54; Overall = .77.

On the attitude questionnaire, the same four factors identified in the original Brekelmans et al. (1990) study were used. The subscales and their coefficients were Appreciation of Lessons (.91), Instructiveness (.85), Easiness (.91), Structuredness of Lessons and Subject Matter (.86), and Motivation for Physics (.91).

All pretests were administered within a 2-3 day period before instruction began formally on the targeted topics. When instruction was completed on the four topics (approximately two months later), all posttests were administered within a 2-3 day period. This was done because one concept was related to another. Gravity, friction, and balanced and unbalanced forces, for example, help to explain the motion of projectiles, so all concepts were taught in an integrated fashion, with teachers reviewing concepts repeatedly.

To evaluate students' learning of the concepts, correlated *t*-tests for the achievement measure scores were run for each class. We had no control group because we were not intervening in the instructional process in any way and were not trying to investigate whether one method of instruction was better than another. We ran regression analyses to see whether answers on the epistemology and attitude questionnaires predicted pre- and posttest achievement on the four achievement tests. Because we ran so many statistical tests, we risked producing significant results by chance. Therefore, results were interpreted as significant only if there was consistency in the findings across statistical measures. For example, if the same factor (such as Simple Knowledge) predicted achievement on a large number of posttests, we could be more certain that the factor was related significantly to the learning of counterintuitive scientific information.

Qualitative procedures. The main focus of our study was qualitative in nature. During instruction, observational data were collected from field notes and videotapes; one researcher spent approximately 30 days in each class during instruction (150 hours total) as a participant-observer, and another researcher spent approximately 15 days (45 hours total) in each class videotaping. During this time, the participant-observer conducted informal and open-ended interviews with the students, talked with the teachers, took field notes, and helped students complete labs and seatwork by answering procedural questions. Although the participant-observer asked students to explain their understanding of the tasks they were completing, she did not explain concepts to them. When the teachers felt they had provided sufficient instruction, the students were tested.

After they had taken the posttests, the students were asked to view and comment on selected videotapes and were asked semi-structured questions (on questionnaires) about their levels of motivation, their experiences with counterintuitive information, their interest in school in general and physics in particular, and the usefulness of physics. (These questionnaires are available from the authors.) Also, after instruction and posttesting, some students in each class who had retained counterintuitive notions were questioned about selected posttest answers, and the scientific notions they had

failed to learn were discussed with them. These discussions were included in field notes and were audiotaped.

Unfortunately, when the questionnaires were distributed, only 6 to 10 of Mark's original students in the general science class could be gathered together at any one time to collect data, because the class had been divided to allow him to assume other duties during that class period. In the regular physical science class, absences became more common toward the time when students were asked to complete questionnaires. On some days, fewer than a dozen students were in class. These circumstances account for the small sample size reported in the Results section.

The field notes and transcriptions of the video- and audiotapes were analyzed for commonalities to be used in coding while the research was still in progress using the method of constant comparison (Glaser & Strauss, 1967). Because students' motivational/behavioral patterns seemed to reflect those described by Lee (1991) and their patterns of dealing with scientific concepts seemed to reflect those described by Hewson and Hewson (1984), the researchers coded the data for evidence of these patterns. This coding was done by two researchers, both of whom had been present during the instruction. The researchers then compared and discussed their coding. When their level of agreement reached .89, the remainder of the coding was completed by one researcher. A second researcher viewed videotapes independently, read field notes, and wrote comments about selected portions of these data sources. These written comments were used to corroborate the coding. Structured interview data were tabulated when appropriate.

RESULTS AND DISCUSSION

Before presenting the results, we wish to emphasize that the students in the three classrooms were at different levels of instruction, used different texts and materials, and, in one class, had a different teacher. Therefore, there are many possible explanations for the differences in the way the students reacted to counterintuitive information. One explanation is that differences in ability were responsible. However, as mentioned earlier, students' intuitive notions were remarkably similar regardless of ability. Another explanation is that the concepts were too difficult for low-ability students to learn. However, our analysis of students' interactions shows that students of all ability levels had sufficient reasoning skills to learn the concepts. For example, when the study was completed and students' difficulties in attaining scientific concepts were discussed with them, all students we spoke with (approximately 85% of the total number of students still coming to class regularly) in both the general and regular physical sciences classes could explain an accepted scientific notion after our demonstrations and explanations. A third explanation is that different instructional styles accounted for differences. Although this report does describe the teachers' instructional strategies, our study did not focus on teachers, but rather on students' reactions to texts and instruction. Teachers' instructional strategies, then, may

help explain results but would have to be the focus of another study to be better understood.

Instruction

In all three classes, the teachers taught concepts about balanced forces, friction, gravity, and projectile motion using the regular textbook chosen for their class and assigning their usual laboratory work. The teachers were told to teach as they would normally: they were free to plan lessons as they wished, and could vary their treatment of topics as they saw fit. For instance, Mark's treatment of the topics was more mathematical than conceptual in the advanced physics class, with the emphasis on mathematical problem-solving, and more conceptual and less mathematical in the general class. He explained that students in the advanced class did not need as much help with the concepts, and that one of the main benefits of the course for advanced students was that physics problems could be used to increase students' problem-solving skills. During instruction, students were also taught information that was not tested by the researchers but was part of the regular curriculum. Students in the advanced class, for example, learned to solve problems with more than one interacting force using vectors. Even though math was emphasized more in the advanced class and there was no math at all in the researchers' tests, math was a focus of all three classes. For instance, all students worked with the equation, $F = ma$ (force equals mass times acceleration). Further, all three classes participated in many more labs than required in the curriculum.

Results of the Pre-Post Tests

On the pretests, all students in all three classes showed that they have intuitive but nonscientific ideas about concepts related to motion. As we expected, however, the students in the advanced class scored higher than the students in the other two classes. As a general rule, students in the regular physical science class scored higher than students in the general physical science class except on the true-false test on gravity. However, several days before the pretest, an informal discussion about gravity had taken place between Mark and several of his students, possibly accounting for their higher score on the pretest.

After instruction, the general physical science students showed significant gains on the Balanced Forces true-false test , $t_{10} = 2.43$, $p = .032$, and the Gravity short answer test , $t_{10} = 2.24$, $p = .049$. There was no change on the Gravity true-false test; however, students may have inadvertently learned about gravity from the informal discussion before the pretest, so that the Gravity pretest was not a true test of prior knowledge for this group. There were no significant gains on any other measure. The regular physical science class gained on the Gravity true-false test, $t_{10} = 2.75$, $p = .021$, and the Gravity application test, $t_{10} = 3.45$, $p = .005$. There were no significant gains on any other measure. The advanced physics students made significant gains on the Balanced Forces true-false test, $t_{22} = 4.54$, $p = .001$, the Balanced Forces application test, $t_{22} = 2.62$, $p - = .02$, the Friction short answer test, $t_{22} = 3.25$, $p = .004$, the Gravity application

Table 1. Results of Multiple Regression - Epistemology Pretest and Achievement Pre- and Posttests

Test	F	Sig of F	Variables	T	Sig T	R^2
Bal Forces T/F Pre	1.74	.1603				
Bal Forces App Pre	5.80	.0009	Simple Knowledge	-4.02	.0002	.20
Gravity T/F Pre	1.56	.2062				
Gravity S-A Pre	3.80	.0112	Quick Learning	-3.91	.0004	.28
Gravity App Pre	1.04	.3987				
Friction T/F Pre	2.25	.0827	Quick Learning	-2.96	.0052	.18
Friction S-A Pre	4.78	.0034	Quick Learning	-3.95	.0003	.29
Friction App Pre	2.82	.0398	Quick Learning	-3.42	.0015	.24
Proj Mo T/F Pre	4.81	.0034	Simple Knowledge	-3.56	.0010	.25
Proj Mo S-A Pre	4.29	.0063	Simple Knowledge	-3.77	.0005	.27
Proj Mo App Pre	1.33	.2771				
Bal Forces T/F	2.44	.0701	Simple Knowledge	-2.67	.0119	.19
Bal Forces S-A	2.01	.1198	Simple Knowledge	-2.89	.0069	.21
Bal Forces App	2.00	.1216	Simple Knowledge	-0.03	.0151	.14
Gravity T/F Post	2.26	.0870	Quick Learning	-2.80	.0087	.20
Gravity S-A Post	2.91	.0386	Quick Learning	-2.96	.0057	.22
Gravity App Post	2.41	.0733	Quick Learning	-3.00	.0054	.22
Friction T/F Post	.99	.4316				
Friction S-A Post	1.23	.3202	Quick Learning	-2.04	.0500	.11
Friction App Post	2.28	.0893	Quick Learning	-2.33	.0269	.16
Proj Mo T/F Post	5.24	.0101	Quick Learning	-3.19	.0034	.26
Proj Mo S-A Post	2.81	.0488	Simple Knowledge	-2.87	.0081	.24
Proj Mo App Post	1.43	.2576	Quick Learning	-2.52	.0187	.20

Test, $t_{22} = 2.95$, $p = .007$, the Projectile Motion true-false test, $t_{22} = 4.67$, $p = .001$, the Projectile Motion short answer test, $t_{22} = 3.57$, $p = .002$, and the Projectile Motion application test, $t_{22} = 2.58$, $p = .02$.

We interpret a statistically significant difference to mean that some sort of conceptual change took place, given the fact that the measures tested understanding of counterintuitive concepts. To perform better on the tests, students had to make some movement toward scientifically accepted notions and away from intuitive ideas, necessitating some form of restructuring of their intuitive notions. The general students showed significant gains on tests of balanced forces and gravity, the regular students made significant gains on tests of gravity, and the advanced students made significant gains on tests of all four topics.

Epistemology Questionnaire

Results of the stepwise regression analyses using the epistemology questionnaire to predict pre- and posttest performance are summarized in Table 1. Simple Knowledge predicted test performance on the Balanced Forces application pretest, true-false posttest, and short-answer posttest. It also predicted test performance on the Projectile Motion true-false pretest, short-answer posttest, and application posttest. Quick Learning accounted for significant predictions of performance on the Gravity short-answer pretest and posttest, the Friction short-answer pretest, application pretest, and short-answer posttest, and the Projectile Motion true-false posttest. In each case, higher scores were predicted for students who did *not* believe in simple knowledge or quick learning. From these results, we conclude that students did better on pre- and posttests if they viewed knowledge as complex rather than simple (knowledge is more than isolated facts), and believed that learning takes time and can be improved through the application of strategies. The amount of variance accounted for by the epistemology measure ranged from 11% to 39%. The Certain Knowledge subscale did not account for performance on any of the pre- or posttests.

Attitude Questionnaire

The attitude questionnaires were used to predict performance on the same achievement tests. The results are summarized in Table 2. Instructiveness accounted for significant predictions of performance on the Balanced Forces pretest and true-false posttest. Structuredness accounted for significant predictions of performance on the Gravity short-answer pretest and posttest, the Friction application pretest and posttest, and the Balanced Forces short-answer posttest. Appreciation accounted for significant predictions of performance on the Friction short-answer pretest and true-false posttest, the Projectile Motion true-false pretest and posttest, short- answer pretest and posttest, and application posttest, and the Balanced Forces application posttest. Apparently, students who liked physics and were comfortable with the structure of the class did better on many of the achievement tests. The amount of variance accounted for by the attitude measure ranged from 39% to 54%. The subscales not predicting performance on any measure were

Table 2. Results of Multiple Regression - Attitude Pretest and Achievement Pre- and Posttests

Test	F	Sig of F	Variables	T	Sig T	R^2
Bal Forces T/F Pre	.65	.6651				
Bal Forces App Pre	3.39	.0166	Instructiveness	3.87	.0005	.33
Gravity T/F Pre	.19	.9651				
Gravity S-A Pre	3.25	.0231	Structuredness	3.30	.0027	.29
Gravity App Pre	1.11	.3847				
Friction T/F Pre	1.86	.1415	Appreciation	3.29	.0028	.29
Friction S-A Pre	4.31	.0065	Appreciation	4.55	.0001	.43
Friction App Pre	5.50	.0018	Structuredness	4.36	.0002	.41
Proj Mo T/F Pre	3.42	.0194	Appreciation	3.93	.0006	.37
Proj Mo S-A Pre	3.19	.0259	Appreciation	3.99	.0005	.38
Proj Mo App Pre	.27	.9257				
Bal Forces T/F Post	5.32	.0020	Instructiveness	4.33	.0002	.40
Bal Forces S-A Post	3.84	.0107	Structuredness	4.06	.0002	.37
Bal Forces App Post	3.83	.0114	Appreciation	3.94	.0005	.37
Gravity T/F Post	2.01	.1133	Structuredness	2.92	.0069	.23
Gravity S-A Post	5.37	.0019	Structuredness	4.61	.0001	.43
Gravity App Post	2.11	.1011	Structuredness	2.63	.0139	.20
Friction T/F Post	4.42	.0066	Appreciation	3.52	.0016	.33
Friction S-A Post	2.17	.0959	Structuredness	2.70	.0123	.22
Friction App Post	3.73	.0160	Structuredness	3.80	.0009	.39
Proj Mo T/F Post	3.41	.0207	Appreciation	3.48	.0018	.33
Proj Mo S-A Post	3.76	.0165	Appreciation	3.92	.0007	.41
Proj Mo App Post	3.07	.0373	Appreciation	3.18	.0045	.33

the Motivation subscale and the Easiness subscale.

Use of Texts in Classes

Four texts were observed in use in the three classes, one each for the advanced and regular classes and two for the general class. The text for the advanced class was *Modern Physics*, published by Harper & Row (1988). In the regular class, the text was *Physical Science*, published by Holt (1984), and in the general class, the two texts were *Concepts and Challenges in Physical Science*, published by Globe (1986), and *Focus on Physical Science*, published by Merrill (1984).

These texts were used differently in each class, even when instruction was by the same teacher. In the advanced physics class, Mark used the text as the primary method of delivering instruction. He divided the course into units and assigned reading, problems, questions, and labwork related to these units. It was the students' responsibility to study the content that was presented, to read and answer the questions in the text, to work the problems, and do the assigned labs, which were collected as reports. Mark viewed his lecture in that class as adjunct to the text, and had originally planned only a few lectures during the year, hoping to add others as he noticed specific problems and difficulties. However, after the first unit in which the researchers were involved, students requested that he plan more lecture/discussions and give them more guidance.

The advanced physics text provided more elaborate explanations of concepts than did the general and regular texts, but Mark disliked the explanations because he thought they sometimes blurred distinctions between concepts for the sake of simplicity. On the other hand, he did like the text's focus on problem solving and mathematics. (A sample of the text can be obtained from the authors.

In the general physical science class, Mark took a different tack. The text was used to reinforce the lecture/discussion. Most of the time, Mark presented material first in a lecture/discussion format. After the students had done some lab investigations, they read the text, which contained the same information Mark presented in the lectures. The text thus served to confirm his lectures, much as it did in the advanced class. This was attested to by a female student who said, "The text is not that helpful. It just tells us what we already know from Mr. K." However, another student said that the text usually added more detail to what they had talked about.

Mark did not assign reading at all outside of class time to general level students, because he was not convinced they would complete the assignments or remember to bring their books back. Rather, he had students read while they were in the class and sometimes he had them answer questions in the book that were related to their reading. To make sure that students attended to the meaning of what they read, he required them to write a "main idea" statement for every paragraph, and he often required them to copy summaries that were in list form into their notes.

Kim, typically, did not assign reading. She used the text as a guide for instruction, however, and tried to tell the students where she

was in the text by giving them a page number. She would then tell students to pay attention to something on a that page, or tell individual students how to use the text to give them information to answer questions. Sometimes she referred students to a picture or an illustration. Other times, she had them do a lab that was described in the text and referred them to that description. She believed that students would not do the reading if she assigned it because some of them could not read very well, so she made sure that she mentioned all the information in the class lecture. Lectures about concepts always preceded labs related to these concepts, and during lectures she asked students questions about processes and examples of processes as she talked about the concepts.

Students' Reactions to Texts

Students' reactions to these texts were varied, but generally negative. As part of the study, students were asked periodically about the value of the textbook and their use of it. In one instance, several days before the first unit test, students in the advanced class were asked if they had read the text yet. They had been working on the labs during class time and had to finish problems, questions, and reading before the test, which was three days away. Of the 23 students asked, 15 had not done the reading yet, six students said they had read the text and liked to read the text before working on problems and doing the labs, and two students read as they worked on the problems so they would know how to do them. This pattern was repeated throughout the study. If students read the text, they were more likely to read it immediately before the test rather than during the period of instruction before the test or while they were working on labs and solving problems.

Some students may have been following Mark's wishes that the text serve to confirm the ideas they gained from lab. Several students commented voluntarily, however, that they did not read the text at all and that nobody did because it was not required and they did not need to. Further, if the text really was confirmatory, it would seem that students would be reading the text immediately after completing a lab. This immediate reading was not generally observed. While 30% of the students made voluntary comments about the helpfulness of the text throughout the quarter, 70% did not. Students were often observed with their books open when working on seatwork assignments such as problem solving, but were not often observed merely reading. Students appeared to be using the text as a resource rather than as a primary means of learning concepts. The text contained questions and problems, and students usually went right to these. As one student said, "The text is really a good problem text. It gives examples of how to work all the problems, but it's not very interesting, otherwise." On only three occasions recorded in the field notes and observed in videotapes did students in the course of discussions spontaneously mention the text as a source of conceptual understanding.

At one point, a male student who was completing a lab said, "Don't you remember reading this?" and went on to discuss concepts about circular motion with his lab partners, who, it appeared, had not read the information. Another male student referred to the text as he was explaining his understanding of a concept to the researcher. A third male student opened the book and read information from the text to his other lab partners as they were completing

a lab. Because the text did not have to be read in class, off-task behavior while reading was not observed. However, off-task behavior was often observed during lab and seatwork periods. Students would talk about social matters and do work for other classes. Mark was not disturbed by this behavior, however, because he felt students would get their work done outside of class. Indeed, several groups of students reported that they regularly got together outside of class to complete their units and prepare for tests.

In the general science class, seven students were asked what was most helpful to them in understanding concepts. All students mentioned the teacher, but only three students said the text was helpful. On only one occasion recorded in the field notes did a student spontaneously mention conceptual information specifically learned from the text. Mark was discussing the idea that objects still accelerate to the ground at the same rate even though they have different levels of horizontal motion, a concept they had discussed previously. One male student said, "Yeah, that's just like the arrows," referring to an example discussed in the text where a dropped arrow would reach the ground at the same time as one that had been shot horizontally.

During seatwork, when general-level students were working on reading assignments, they often made disparaging comments about their work. For instance, a male student challenged Mark during a reading assignment for which students were asked to write main idea sentences and copy the summary information (approximately five numbered sentences). He said, "Why do we have so much work in here?" Mark replied that he thought that was the idea of school. The student countered with, "Yeah, but this is copy work. I hate this." In fact, much of the off-task behavior and disruptiveness occurred during reading seatwork. Of the 60 off-task or disruptive incidents coded in the field notes and videotapes in this class, 30 occurred during seatwork assignments, and 25 of these were during reading assignments. (The other five occurred during math assignments.) Students often talked about social matters while they were "reading." Inattentiveness while reading and doing seatwork was a main feature of this class.

Students did not seem to like the textbook in the regular physical science class, either. When six students in this class were asked what was the most helpful to them in understanding concepts, only one mentioned that the text was helpful. In fact, students were rarely observed reading the text independently, although they did read their notes, questions, and lab materials. There were no observations in the field notes where students spontaneously mentioned concepts learned from the text. Most of the questions they answered were not in the text, but were a part of their lab work, and students would refer to their notes to answer questions rather than read the text. Since they were not assigned reading to do in class, they did not exhibit off-task behavior and disruptiveness during reading seatwork. (However, they were observed being off-task and disruptive while doing labs, answering questions, and listening to lectures, and, like the General class and the advanced physics class, often talked about social matters while working.)

Cross-Class Analysis of Textbook Use

Our observations were that texts were perceived negatively by students and at least somewhat negatively by the teachers. At the end of the study, however, students completed

a questionnaire on which they were asked the question, "What do you do that helps you understand concepts in physics?" Under these conditions, students more often mentioned reading as a source of understanding. Twelve out of 25 students (48%) in the advanced class, 6 out of 8 (75%) students in the general class, and 5 out of 9 students (56%) in the regular class mentioned that they read as one of the main ways to learn concepts in physics. We should note, however, that reading the textbook was not always mentioned; students may have been referring to reading notes or other materials or working on problems in their textbooks. Also, the class with the highest percentage of responses about the helpfulness of the text was the general class, the class where text reading was assigned and expected to be completed during class time.

Despite negative reactions, our observations indicate that texts were an important part of all three science classes. Even when having students read the textbook was not perceived as important, the textbook still functioned as a guiding force in the curriculum. Kim based her lesson plans on the texts, even though she did not require students to read. The primacy of textbooks in the classroom has been previously noted by Yore (1991), who reported that the science text is the main way instruction is delivered. When having students read the text is perceived as important (as in Mark's two classes), however, it often falls short of being effective at sustaining students' attention, providing necessary information, or enhancing students' understanding of concepts. The inadequacy of science texts in helping students learn or change concepts has been noted previously in the literature (e.g., Glynn, 1991; Britton, 1991).

Why texts are so ineffective is a matter of discussion. Glynn notes the lack of effective use of analogy to help explain concepts, and Britton notes conceptual gaps that require students to make inferences they are not capable of making because they lack prior knowledge. These researchers share the idea that texts should make ties between new information and students' existing frameworks. These ties may be even more important when the new information is counterintuitive, because to change concepts, students must be aware of their existing conceptions. Simply evoking a student's prior knowledge, however, does not seem to be adequate. Researchers (most recently Chinn & Brewer, 1993) have noted that strongly held beliefs form a framework for judging the validity of new information and increase the likelihood that new information will be ignored or rejected. Therefore, not only must prior knowledge be evoked, it must also be questioned so that students may revise their previous notions.

A meta-analysis by Guzzetti, Snyder, Glass, and Gamas (1993) found that refutational text was more effective than regular text at producing conceptual change in students. Refutational texts are designed to at least partially meet Posner, Strike, Hewson, & Gertzog's (1982) conditions for conceptual change. That is, for conceptual change to take place, the old theory must appear inadequate and the new theory must be understandable, plausible, and useful. A conclusion from previ-

ous research using this type of text is that refutational text is more successful than regular text, demonstration, or group discussion in producing long-term conceptual learning of counterintuitive information (Alvermann & Hynd, 1989; Hynd, Alvermann, & Qian, 1993; Hynd, McWhorter, Phares, & Suttles, in press). Whether or not refutational text is successful because it causes cognitive conflict, because it authoritatively confirms what has already been covered through discussion and lab, or because it provides readers with a coherent and understandable explanation of the new theory is still unclear. In addition, refutational text has only been studied within the confines of short-term experimental studies. Its effectiveness under naturalistic conditions is only a matter of conjecture. Indeed, in the general class, portions of the textbook were noted as refutational by the researchers, but no change in behavior while reading these portions of the text was observed except in one or two cases. The one incident in which a student noted a concept learned from the text in a subsequent discussion was a concept presented in refutational style.

The research on refutational text is pertinent to this study because it provides a potential remedy for the problems of the instructors and their students. Kim was not convinced that the text was useful to her students, although it was useful to her. Mark believed in the usefulness of texts but was concerned about the quality of the textbooks in both classes. In the general level class, he changed books but still felt that the book was not as good as it could be because of the simplistic explanations it provided. Although he had originally liked the advanced physics text because of its strength in explaining mathematical problem solving, he became convinced, partially as a result of this study, that it did not do an adequate job of explaining physics at a conceptual level, and that his students were having difficulty solving novel problems because they lacked conceptual knowledge. He planned in the following year to use portions of Hewitt's *Conceptual Physics* (1992), a text noted by Glynn (1994) as showing exemplary use of analogies. He also advocated the introduction of short refutational texts to students after they had participated in labs and discussed counterintuitive ideas. Kim, too, because her students still had difficulty with counterintuitive notions after her instruction, was willing to have students read refutational texts in addition to taking notes on lectures, participating in labs, answering questions, and solving problems.

Effect of Cognition, Attitude/Motivation, and Sociocultural Factors on Conceptual Change Learning from Text

As can be seen from the pre-post data presented in Table 2, students began instruction with intuitive beliefs that ran counter to scientific notions. Although the advanced physics students improved their scores significantly on many of the measures and the other students improved on only one or two of the measures, in no instance did the mean score approach the total number of points possible. Even students in the advanced classes, then, ended the study with incomplete learning of counterintuitive

ideas. In the following discussion, the role of cognition, attitude/motivation, and socioeconomic factors will be dealt with separately and then considered in a more integrated way in the conclusion.

Cognition. According to Posner, Strike, Hewson, & Gertzog (1982), cognitive conflict between existing beliefs and new information must be experienced before conceptual change can take place. Further, in Guzzetti, Snyder, Glass, and Gamas's (1993) meta-analysis, most successful instructional techniques included an attempt to elicit conflict. In this study, concepts related to balanced forces, gravity, and projectile motion were highly counterintuitive to students, as the posttest results indicated and as the intuitive but nonscientific ideas that students espoused during interviews and informal discussions revealed. In the general physical science class, students (mostly male) often voiced and defended their intuitive notions during class discussion, making it evident to the researcher that cognitive conflict was taking place. In the advanced physics class and in the regular physical science class, however, students were not as vocal about defending their intuitive ideas, making it difficult to discern any conflict between existing notions and new information. Mark used the comments students made in the general class to structure further discussion and questions around their intuitive ideas. Students understood that this engagement in discussion helped them learn. For instance, in response to viewing a video of such a discussion one female student remarked, "They (students) were trying to figure out what was the answer to the question he gave and were trying to discuss whether it was yes or no." When asked if the students were learning, she replied, "Yes! Because they were trying to imagine the problem and every answer came up slightly different because they were arguing about who was right and who was wrong."

An excerpt from another of these discussions follows. The discussion begins with Mark explaining that objects fall at a constant rate of acceleration of 9.8 m/s^2.

MARK: If I'm holding an object and I drop it, gravity is going to pull it down to the ground.

STUDENT 1: Yep.

MARK: And I time it, and I let if fall for one second, it is going 9.8 meters per second at the end of one second. At two seconds, it has speeded up to 19.6. After three, it has speeded up to 29.4 ... (Mark then explains the same thing using miles)

STUDENT 2: How do you know that?

STUDENT 3: Now, but wait. Doesn't it depend on the shape?

MARK: Now wait a minute. I thought we had already decided that if you take two objects and release them, then you...

STUDENT 3: That's not really true though, man.

MARK: All right. Hang on. What's not true about it?

STUDENT 3: You don't know if it's 32 feet per second.

MARK: Why do I not know that?

STUDENT 3: 'Cause somebody might be fat and somebody might be skinny. It depends on the weight and shape.

MARK: What do the weight and shape have to do with it?

STUDENT 3: It depends on where the air flows.

MARK: Okay. So you're starting to think about what air's got to do with it, and I'll agree with you 100%.... The point I'm making to you is, that with these numbers, he's right. [STUDENT 3] is right. These are not iron-clad numbers. The air-resistance is going to affect them. If I drop a styrofoam ball, is a styrofoam ball going to drop at 96 ft per second? No way. If I drop a lead ball...

STUDENT 4: Yeah.

MARK: Yeah. I think that it's going to hit pretty close to 96 ft per second. I want to argue a point here. Now [STUDENT 3] said that the shape is going to influence it, which I agree... (*At this point, all of the male students are talking among themselves about the problem*) ...guys...that the shape is going to influence it, but he also said the weight is going to influence it. If I drop a penny and a nickel, are they going to fall at the same rate?

SEVERAL STUDENTS: Yep ... No

STUDENT 5: It depends on how you drop the penny.

MARK: Yeah, they will fall at the same rate.

STUDENT 5: Naw.

MARK: You were right though (nodding to Student 3), but it's not the weight. It's the shape of the object that will influence it 'cause of the way the air flows around it.

(*Class continues with Mark developing the notion that the differences in shape between a penny and nickel aren't great enough for air to influence their fall.*)

As can be seen in this excerpt, Mark is able to appropriate students' comments and use them to structure his discussion. In the advanced physics class, however, his lectures often focused on mathematical problem solving and, although they were related to concepts, students rarely asked questions about concepts. They were mostly about equations, and those questions were rare. In labs, students' intuitive ideas were only slightly more evident. As Mark met with groups of lab partners, he would sometimes engage them in discussion about concepts using the same techniques noted

in his discussion with the general class. Students in the advanced class, however, did not often argue for their intuitive notions. Instead, they would ask questions and listen to explanations. The researchers did observe, however, that students in the advanced class also engaged other students in conversations about the ideas they were studying and helped each other with mathematical problems and sometimes with conceptual difficulties. Often, through discussion, they would catch contradictions in their thinking and change their notions.

Students in the regular physical science class also rarely engaged in the type of discussion noted in the general class. An excerpt from a typical class discussion follows. The topic of the lesson is balanced forces.

(On the overhead is written: A force is a push or pull which causes objects to move, change speed or direction, or stop moving.)

KIM: What does a white cue ball do to the pool table? What is the force in that example?

STUDENT 1: The stick.

KIM: What actually caused the balls to move?

STUDENT 2: The cue.

KIM: What happens when a cue ball hits another ball?

STUDENT 1: They go in different directions.

KIM: Where does the force go?

STUDENT 1: To the other one.

(Kim reveals on the overhead the following: Forces act when one object is in contact with another.)

KIM: Can anyone think of an example?

STUDENT 3: Cars.

KIM: What force is in action when a car is in motion?

(No one answers)

KIM: [student], what are you doing in your chair? ([student] is leaning back against the wall) Is the wall creating a force?

UNIDENTIFIED STUDENT: I think so.

KIM: The wall has a force against [student], just like [student] has a force against the wall. If you stand on the floor, the floor is pushing back. Later on today, we'll talk about balanced forces.

This discussion is significant because, in the general class, when Mark talked about a floor or a wall pushing back, the idea met with vehement disapproval and initial rejection from students. They argued that a stationary, inanimate object would not be capable of exerting a force. In an example of a ball hitting a wall, for example, they agreed that the ball exerted a force against the wall, but had difficulty with the idea that the wall exerted an equal force against the ball. After discussion, they read information about balanced forces in their class and diagrammed opposing forces that existed when a ball rested on a table. At that point, they seemed to grasp the idea. Indeed, the

general class increased their scores from pre- to posttest on the Balanced Forces true-false test. When students in the general class were questioned further about their test answers after instruction, some were still having difficulty accepting the concept, but clearly remembered the in-class discussion and were able to articulate the scientific notion and its difference from their own.

The regular physical science class improved their pre-post scores on the Gravity tests only. Importantly, the gravity discussion was the only one in which students were engaged in defending their intuitive notions. One day, Kim asked students what would happen if a heavy object and a light object were dropped from the same height at the same time. Students answered that the heavy object would fall first. When she had students perform the experiment, they argued that the objects had been dropped wrong. It took a number of trials performed by different students with a variety of objects before students began to accept the notion that objects all accelerate downward at a constant rate. Two students, in particular, argued with Kim until the end of the period.

STUDENT 1: Let's say a big and a little person fall at the same time. You mean they hit at the same time?

(They complete more trials of the experiment.)

STUDENT 2: Not a big, fat lady, though.

Students in this class were interviewed after the posttest and asked about their notions of gravity. While many students still exhibited intuitive nonscientific notions about gravity, they all, when questioned, remembered the day when objects were dropped and remembered that the objects hit the floor at the same time. One of the two students who was most vehement in rejecting the counterintuitive concept said, "That's the only day I remember in the whole year."

Cognitive conflict was noted in the advanced class, also, but most noticeably when it was elicited by the researcher after instruction had been completed and students had completed the posttests. The researcher took students aside who had not done well on the Gravity or Projectile Motion posttests and asked them to explain their answers on the test. Sometimes, as students began to explain, they would stop themselves as they noted contradictions in their arguments. The notion of what happens when a projectile is launched off a cliff can be used as an example. Many have the naive idea that the object will travel horizontally for some time *before* falling, when, actually, gravity and momentum act simultaneously, causing the object to curve in an arc to the ground. One male student explained:

> It has increasing speed so it will keep going in the same direction before gravity has an effect...I guess...there's a level surface. I guess it has constant speed, but it'll go out before going down.

When asked what forces were operating, he said:

> Well, there's the force that pushes it forward and there's gravity. Gravity would act almost immediately, but I'm not sure...No, the forward force will decrease and then gravity will take over. I never really got that

straight in class. No, I think gravity pulls it down immediately. That's it.

Sometimes students did not catch their contradictions. At that point, a researcher discussed the concepts with them, and in the case of gravity, demonstrated that objects fell at the same accelerating rate. While most students were surprised, they generally accepted the notion. Several students asked why, if a heavier object had more force, it did not fall faster. They did not realize that in the equation $F = ma$, the force would be higher if the mass were larger and the acceleration were constant. They missed this concept even after doing a unit that included several labs varying one factor in the equation and keeping another constant. One student became disturbed that he had misunderstood much of the work up to that point in the year. He berated the researcher for presenting the counterintuitive notion in such an abrupt manner. Later, he read everything in the textbook that had to do with gravity, went to the library to find other information, and discussed his failure to understand gravity with his teacher.

As a review of the posttest scores shows students in the advanced class significantly improved many of their posttest scores, even though evidence of cognitive conflict relating the targeted concepts had been scanty during instruction. In order to determine whether or not cognitive conflict had occurred, we asked students in all classes if they had ever experienced a time in their science class when what they were learning was not what they had previously thought. Of the 25 students in the advanced class who answered the question, 18 said that they had; they mentioned concepts related to balanced forces, friction, projectile motion, and gravity as producing conflict. Eight of the students experiencing conflict about gravity had experienced conflict not from regular instruction but through intervention of the researcher, who had taken these students and tried to elicit conflict about their intuitive conceptions. Ten of the 18 students, however, were not targeted for researcher confrontation. In the general physical science class, all eight of the students who were present the day of the question said they had experienced conflict and mentioned balanced forces, projectile motion, and gravity as being sources of the conflict. In the regular physical science class, only two out of nine students reported conflict, with the conflict occurring about gravity. Because this question was asked before the interviews about the tests had been completed in the regular class, the students were asked again after a researcher had interviewed them; the number of students reporting conflict then jumped to four of the nine students.

To explore students' ideas about their thinking further, a researcher discussed Hewson and Hewson's four (1984) options for handling new information with students and had them choose which option matched their behavior. In the general and in the advanced classes, students most often noted that they changed their existing ideas in response to conflicting new information. In the regular class, however, students most often reported memorizing or assimilating new information.

These results do not necessarily support the idea that *awareness* of cognitive conflict is a necessary condition for conceptual change. It does provide some support for the notion that cognitive conflict is an important factor in conceptual change, although it may not be sufficient. When cognitive conflict was noted by students, some reported feeling good about what they had learned, while others reported

Table 3. Classification of Students Using Lee's Motivation Scale.

	Advanced	Regular	General
Researcher Rating	(n = 26)	(n = 15)	(n = 18)
Mot/Int Motivated	21/81%	3/20%	4/22%
Intrinsic/Inconsistent	5/19%	6/40%	5/28%
Extrinsic	0	3/20%	2/11%
Not Motivated/Disruptive	0	3/20%	7/39%
Student's Self-Rating	(n = 21)	(n = 9)	(n = 8)
Mot/Int Motivated	16/73%	2/22%	3/37%
Intrinsic/Inconsistent	5/23%	5/56%	1/13%
Extrinsic	0	1/11%	4/50%
Not Motivated/Disruptive	0	1/11%	0

feeling surprised, confused, shocked, and misinformed, attesting to the power of such conflict at an emotional level.

In summary, students find basic scientific concepts dealing with motion difficult to learn, even in advanced classes. While conflict between new ideas and existing notions appears to be a powerful factor, it may not be a sufficient one for conceptual change. If the mere presence of conflict were sufficient, it seems reasonable that students in the general class, who apparently experienced the most conflict, would have improved on more of the posttest scores. Further, students may not be aware of experiencing conflict, but be influenced by it nonetheless. Students in the regular class demonstrated conflict about gravity and improved on their gravity posttests, but many did not report feeling conflicted.

Attitude/Motivation. Field notes and transcripts of videotapes and interviews were coded for evidence of behaviors reflecting Lee's (1991) six motivational patterns discussed previously. As the coding proceeded, the researcher found it too difficult to separate intrinsically motivated behaviors from motivated behaviors, so Patterns 1 and 2 were coded together. Intrinsic motivation, motivation, and intrinsic-but-inconsistent motivation were operationalized as (a) questions reflecting a need to understand a concept, (b) comments about a concept reflecting an attempt to understand it, and (c) uninterrupted on-task behavior during assignments. Intrinsic-but-inconsistent was distinguished from intrinsic motivation when the student exhibited both intrinsic and extrinsic or intrinsic and non-motivated behaviors.

Extrinsically motivated behavior was operationalized as (a) questions reflecting a need to understand procedures and policies, (b) comments about procedures and policies, and (c) on-task behavior during seatwork interrupted by periods of off-task behavior or on-task behavior accompanied by inaccurate but complete assignments. Unmotivated behavior was operationalized to include all off-task but nondisruptive behaviors such as sleeping and

resistance to task completion. Unmotivated and disruptive behavior was operationalized as including all disruptive incidents. Also, after instruction, Lee's (1991) classification scheme was explained to some of the students in the class, and they were asked to rate their levels of motivation. These data are presented in Table 3.

In the general class, students did not classify themselves as being unmotivated, although students were present who had been classified by the researcher as such. Students who said they had extrinsic motivation were either students who were classified by the researcher as being not motivated or classified by the researcher as having inconsistent motivation. Perhaps they were right. In reviewing the field notes and videotapes, the researcher noted instances in which the four students who classified themselves as having extrinsic motivation slept or were otherwise inattentive during discussions, but woke up and at least began working when seatwork was assigned. Perhaps they perceived their behavior (waking up to work on seatwork) as evidence of their concern with getting work done for a grade. Students, on the whole, however, exhibited more motivated behavior during lecture/discussion than during seatwork or labs. Although labs are thought to be motivating, Mark often required students to do math. Students uniformly had difficulty doing the math, and since only one student brought a calculator, problems were figured out in a very tedious way. In the advanced class, neither researchers nor students classified themselves as unmotivated or disruptive. Motivated behavior occurred during seatwork/lab assignments, because during/lecture discussion, most students sat passively.

In the regular class, the most disruptive student classified himself as having inconsistent motivation because he "could do it" if he tried. In this class, off-task and disruptive behavior occurred both during labs and seatwork and during lecture/ discussion. Most notably, three students were often disruptive during lecture/ discussion, so that there were many more interruptions than in the general or the advanced classes. Also, although only a few students were classified as being extrinsically motivated, more students in this class asked questions dealing with procedures than in the other two classes, reflecting a more extrinsic orientation in the class overall.

Motivation levels complement the questionnaire data on attitudes. Although the motivation subscale of the attitude measure was not notable, the questions asked of students seemed to be tapping variables other than those coded in the field notes. For instance, watching television shows about physics, using physics in leisure time, and doing experiments at home are not typical high school activities, even for students who are motivated to learn physics. Students who like physics and are happy with the way physics class is structured are likely to exhibit the behaviors coded as motivated. Also, students who have the idea that knowledge is complex and that effort is needed to learn that knowledge are more likely to expend that effort if they like physics and the structure of the physics class. Therefore, the epistemology scale also complements these data. Indeed, when students were asked what they did to help them learn concepts in physics, students in the advanced class (who were more motivated) reported more varied strategies than the other two classes.

In considering the effect of attitude and motivation on conceptual change, Pintrich, Marx, and Boyle (in press) argue that Posner, Strike, Hewson, and Gertzog's (1982) model presents a model of "cold conceptual change," in that it assumes that "when faced with a discrepancy between a current framework and new, to-be-learned concepts, a student would undergo an unfreezing of her cognition in order to seek specific cognitive closure, that is, the resolution of the discrepancy" (p. 24). They argue that a learner's motivation to learn new information may determine whether this unfreezing actually takes place.

We believe that high levels of motivation at least partially explain why the advanced students changed their conceptual understandings to scientific ones more often than the general or regular physical science students, even though they did not exhibit as many signs of cognitive conflict as students in the general class. Of course, the advanced students knew more to begin with and were perceived as having more ability. But, although a higher level of prior knowledge is certainly a factor in learning, its role in conceptual change learning is not clear. Further, the concepts seemed as counterintuitive to the advanced students as they did to the general students. Finally, understanding the new information was not the problem the general class experienced. Rather, accepting the new information appeared to be the problem. That is, students remembered and could describe the results of demonstrations and the discussions about counterintuitive ideas, especially when they argued for their intuitive notions. However, they often continued to answer questions about these ideas based upon their intuitive beliefs.

Socioeconomics, tracking, and relevance. Pintrich, Marx, and Boyle (1993) challenge the notion that science students in school are "child-scientists" and that the classroom is a "community of scientists." Students' goals and their understanding of their roles may not be what educators would like them to be. To explore students' concepts of their place in the educational and scientific community, students were asked to describe and rate, on a 10-point scale, the importance of education as perceived by their parents, to describe and rate the importance of education as they perceived it, to rate and explain the importance of learning information in physics class, to describe how they intended to use the information they learned in physics, and to describe their education and career goals. Students' ratings of parents views were: (advanced) 9.7, (regular) 9.4, (general) 8.0. Students' ratings of their own views were: (advanced) 8.3, (regular) 9.3, (general) 7.0. Ratings of the importance of physics were: (advanced) 7.7, (regular) 7.1, (general) 5.8.

Although the regular class nearly equaled or surpassed the advanced class in their ratings of the importance of education and physics, they had a more difficult time figuring out how they would use the "important" information they learned in physics, and their answers about usefulness were similar to those of the students in the general class. When students were asked how they planned to use the information they learned in physics class, only 8% said they did not know or did not think they would use it. All other students mentioned using the information on the job, at college, and/or to help them understand everyday occurrences. In the general class, no student said they would use

the information in the future. In the regular class, 72% could think of no way to use the information in the future. The others said they would use the information to pass on to others or to help them understand life.

This lack of usefulness may be tied not only to track but to students' career goals, in that, even when students said they wished to go to college, students in the general and regular classes chose nonscientific careers, while students in the advanced class chose mostly scientific professions. We believe that some students in the two lower-level classes felt they were not able to become scientists. We can think of no other explanations as to why students who rated themselves as highly motivated to learn science and who were perceived as being highly motivated by the researcher would be unable to think of a use for the information.

A lack of access also explains students who lack motivation. As one student said in an interview, "I wanted to be an engineer, but I guess that's not going to be possible. Now I don't know what I want to do, so I can't really get motivated to learn anything." Another student (this time in the general class) said, "I'm going to be an auto-body repairman. I don't need this stuff." The student with the most significant behavior problem in the regular class said, "When I get out of school, I'm going on the street. I don't need to know science." In contrast, students in the advanced class often made comments reflecting their need to know scientific information. For instance, the student who became so concerned that he had not learned scientific explanations of gravity commented, "I need to know this stuff. I'm going to be an engineer." Also, because of their access to scientific careers, they seemed to have fairly sophisticated notions about the kind of behavior scientists would exhibit. One male student said, "Physics is a way of thinking that is different sometimes from logic. Like with gravity. Logic would tell you that a heavier object would fall first, but the physical principle is that heavy and light objects fall at the same rate. Physics is a way of teaching your mind to not look at the surface, but to look more into it." This student explained that his father was a scientist and that he grew up with scientific ideas. He was going to be a scientist, also, and he thought the physics class would look good on his transcripts. While it is a matter of conjecture that the career choices reported by students in this study were motivated by social class, the clear delineation between the advanced and the two lower-level classes regarding social class is notable. In the advanced class, no student was receiving free lunch. In the other two classes, most students were.

The students in the lower-level classes in this study often exhibited the behaviors anthropologists have documented as being a consequence of the mismatch between socioeconomic class and the school environment. When students are perceived as being lower-class and therefore different from teachers, the perception of difference results in differential treatment, although it is unintentional (McDermott, 1987). Students feel out of place and accept their status as disenfranchised individuals. By the time students get to high school, disenfranchised behavior may be entrenched. Students who do not see the relevance of education may have lowered motivation and per-

formance as a result. We believe, therefore, that relevance to career goals is a central factor in determining conceptual change. Many students appeared interested in understanding principles of motion in the general physical science class. However, they may not have been motivated to actually change their counterintuitive notions because they could see no useful reason for doing so.

The motivation scale on the attitude measure, however, while it included some items that seemed to concern relevance, did not turn out to be a significant factor in posttest achievement. For this reason, the role of relevance should be explored further.

Other factors. A possible explanation for the general physical science class's lack of conceptual change on more items may be that the students were not good test-takers. In support of this idea, students who were asked to explain their answers on the true-false posttests often did much better at explaining counterintuitive ideas than their test scores would suggest. One female student in the general science class, for instance, would have scored 18 out of 20 points on the Balanced Forces test had the test items been read to her individually and she had been allowed to answer orally. However, her achieved score was only 13 out of 20 when she took it in the group, even though the items were read to her. Also, when writing was required, students tended to write "I don't know" instead of writing their thoughts because they perceived writing as a difficult task. When asked to explain items during the interviews, they often caught their own errors, as did the student in the advanced class who corrected his mistake regarding the path of a projectile. Lack of motivation partially explains these students' test performances, too.

CONCLUSION

In this study, we investigated the role of text and of cognition, attitude/motivation, and socioeconomic relevance in conceptual change about concepts of motion. Although the text was central to instruction in all three classes, it was not perceived as being very successful at inducing conceptual change and was viewed somewhat negatively by both teachers and students. Students were often disruptive and inattentive during reading and other seatwork assignments. Refutational text is an alternative to the regular text, which both teachers in the study would now like to try.

Although cognitive factors appear to be important, they operate in concert with motivational and socioeconomic ones. As for cognition, the experience of cognitive conflict appeared to be a necessary but insufficient condition for conceptual change, in that some students who were observed experiencing conflict failed to improve their scores from pretests to posttests. This conclusion is confounded by the fact that some students did not report feeling conflict even when they were observed experiencing it. Awareness of conflict remains to be studied.

Attitude/motivation and socioeconomic relevance may affect whether students persist in changing their existing notions after they have experienced cognitive conflict. Students in the three classes differed in their levels of motiva-

tion were less likely to change their intuitive notions than students with high levels of motivation. High levels of motivation, as manifested in behavior, however, did not guarantee that students learned counterintuitive material. Perceived relevance of the material may be equally important. Students who believe that science is irrelevant to their lives may not be motivated to learn. One would expect, then, that there would be more conceptual change in a class where students expected to use the information in their careers than in a class where students chose careers not requiring knowledge of physics. The choice of careers, too, may be motivated by socioeconomic class. We found it notable that the classroom environment appears to be at least moderately tied to students' achievement and learning. Students who appreciated the atmosphere and structure of their physics classes tended to do better on outcome measures. Also, one's belief about the nature of knowledge also appears to be moderately tied to student achievement concerning counterintuitive notions. Students who expected knowledge to be complex and not just a collection of facts tended to perform better. Also, students who had some procedural knowledge for learning information performed better. These findings would suggest that instructing students in how to study counterintuitive information may be a viable way to improve learning. Indeed, Guthrie et al.'s (1994) study supports the idea that helping students search for, comprehend, and integrate relevant scientific information enhances learning.

A combination of cognition, motivation, and relevance helps explain why some students change their intuitive notions to scientific ones and others do not. Perhaps relevance is the driving force of the three. If physics is not perceived as relevant, it seems unlikely that students would expend the effort to learn it, particularly when it is so counterintuitive.

As for future directions, we believe that, because of the textbook's visibility but perceived lack of effectiveness, studies attempting to increase its effectiveness are worthy of consideration. Although refutational text has been effective in experiments, we question whether this type of text would be equally effective in naturalistic environments, or whether others (e.g., texts that have been rewritten to close inferential gaps [Britton, 1991] or texts in the form of trade books) would be equally effective. We would also like to explore whether placement of texts in the instructional environment is important and if texts are effective, we would like to find out why. Finally, we wish to see whether improving students' procedural knowledge about learning from texts increases their understanding of counterintuitive ideas.

The role of cognitive conflict in conceptual change is another area worthy of study. We feel that cognitive conflict is an important variable in conceptual change, but there should be ways to document its occurrence and to determine whether a student's metacognitive awareness of its occurrence has any effect on subsequent change. Finally, we wish to look at teachers' epistemologies and to determine how these epistemologies affect their structuring of a classroom to make it conducive to learning counterintuitive information.

Authors' Note. Copies of the tests and questionnaires used in this study and text samples from the physical science books used by the participating teachers are available from the first author. Direct all correspondence concerning this report to: Cynthia R. Hynd, National Reading Research Center, 318 Aderhold, University of Georgia, Athens, GA 30602.

REFERENCES

Alvermann, D. E., & Hynd, C. R. (1989). Effects of prior knowledge activation modes and text structure on nonscience majors' comprehension of physics. *Journal of Educational Research, 83*, 97-102.

Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (1991). Motivating project-based learning: Sustaining the doing, supporting the learning. *Educational Psychologist, 82*, 24-32.

Brekelmans, M., Wubbles, T., & Creton, H. (1990). A study of students' perceptions of physics teachers' behavior. *Journal of Research in Science Teaching, 27*, 335-350.

Brown, D. W., & Clement, J. (1987, April). *Overcoming misconceptions in mechanics: A comparison of two example-based teaching strategies*. Paper presented at the meeting of the American Educational Research Association, Washington, DC.

Champagne, A. B., Gunstone, R. F., & Klopfer, L. E. (1985). Instructional consequences of students' knowledge about physical phenomena. In L. H. T. West & A. L. Pines (Eds.), *Cognitive structure and conceptual change* (pp. 61-90). New York: Academic Press.

Chinn, C. A., & Brewer, W. F. (1993). The role of anomalous data in knowledge acquisition: A theoretical framework and implications for science instruction. *Review of Educational Research, 63* (1), 1-49.

Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative research*. New York: Aldine Press.

Glynn, S. M. (1991). Explaining science concepts: A teaching-with-analogies model. In S. M. Glynn, R. H. Yeany, & B. K. Britton, (Eds.), *The psychology of learning science* (pp. 219-240). Hillsdale, NJ: Erlbaum.

Glynn, S. M. (1994). *Teaching Science with Analogy: A Strategy for Teachers and Textbook Authors* (Reading Research Report No. 16). Athens, GA: National Reading Research Center, Universities of Georgia and Maryland.

Glynn, S. M., Yeany, R. H., & Britton, B. (1991). A constructive view of learning science. In S. M. Glynn, R. H. Yeany, & B. K. Britton (Eds.), *The psychology of learning science* (pp. 3-19). Hillsdale, NJ: Erlbaum.

Guthrie, J.T., McGough, K., & Bennett, L. (1994). *Concept-oriented reading instruction: An integrated curriculum to develop motivations and strategies for reading* (Reading Research Report No. 10). Athens, GA: National Reading Research Center, Universities of Georgia and Maryland.

Guzzetti, B. J., Snyder, T. E., Glass, G. V., & Gamas, W. S. (1993). Meta-analysis of instructional interventions from reading education and science education to promote conceptual change in science. *Reading Research Quarterly, 28*, 116-161.

Hewson, P. W., & Hewson, M. G. (1984). The role of conceptual conflict in conceptual change and the design of science instruction. *Instructional Science, 13*, 1-13.

Hynd, C. R., & Alvermann, D. E. (1989). Overcoming misconceptions in science: An on-line

study of prior knowledge activation. *Reading Research and Instruction, 28* (4), 12-26.

Hynd, C. R., Alvermann, D. E., & Qian, G. (1993). *Prospective teachers' comprehension and teaching of a complex science concept* (Reading Research Report No. 4). Athens, GA: National Reading Research Center, Universities of Georgia and Maryland.

Hynd, C. R., McWhorter, J. Y., Phares, V. L., & Suttles, C. W. (in press). The role of instructional variables in conceptual change in high school physics. *Journal of Research in Science Teaching*.

Lee, O. (1991, April). *Motivation to learn subject matter content: The case of science*. Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL.

Maria, K., & MacGinitie, W. (1981, December). Prior knowledge as a handicapping condition. Paper presented at the annual meeting of the National Reading Conference, Dallas, TX.

McCloskey, M. (1983). Intuitive physics. *Scientific American, 248*, 122-130.

McDermott, R. (1987). Achieving school failure: An anthropological approach to illiteracy and social stratification. In G. D. Spindler (Ed.), *Education and cultural process* (pp. 173-209). Prospect Heights, IL: Waveland Press.

Nussbaum, J., & Novick, S. (1982). Alternative frameworks, conceptual conflict, and accommodation: Toward a principled teaching strategy. *Instructional Science, 11*, 183-200.

Osborne, R., & Freyberg, P. (1985). *Learning in science: The implications of children's science*. Auckland: Heinemann.

Palincsar, A. S., & Brown, A. L. (1984). Reciprocal teaching of comprehension-fostering monitoring activities. *Cognition and Instruction, 1*, 117-175.

Pintrich, P. R., Marx, R. W., & Boyle, R. (in press). Conceptual change and student motivation in the classroom context. To appear in A. Pace (Ed.), *Beyond Prior Knowledge: Issues in Text Processing and Conceptual Change*. New York: Ablex.

Pintrich, P. R., Marx, R. W., & Boyle, R. (1993). Beyond cold conceptual change: The role of motivational beliefs and classroom contextual factors in the process of conceptual change. *Review of Educational Research, 63* (2), 167-199.

Posner, G. J., Strike, K. A., Hewson, P. W. & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education, 66*, 211-227.

Qian, G. (1993). *Overcoming naive theories in secondary students' learning of science concepts from text: The role of immature epistemological beliefs and learned helplessness*. Unpublished doctoral dissertation, University of Georgia, Athens, GA.

Raudenbush, S. W., Rowan, B., & Cheong, Y. F. (1993). Higher order instructional goals in secondary schools: Class, teacher, and school influences. *American Educational Research Journal 30*, (3), 523-554.

Resnick, L., Levine, J., & Teasley, S. (1991). *Perspectives on socially shared cognition*. Washington, DC: American Psychological Association.

Schommer, M. (1990). Effects of beliefs about the nature of knowledge on comprehension. *Journal of Educational Psychology, 82*, 498-504.

Strike, K. A., & Posner, G. J. (1990). A revisionist theory of conceptual change. In R. Duschl & R. Hamilton (Eds.), *Philosophy of science, cognitive science, and educational theory and practice*. Albany, NY: State University of New York Press.

Swafford, J. (1989). *The effects of a science text and demonstration on conceptual change of high school students*. Unpublished doctoral dissertation, University of Georgia, Athens, GA.

Wolcott, H. F. (1987). The teacher as an enemy. In G. D. Spindler (Ed.), *Education and cultural process* (pp. 136-150). Prospect Heights, IL: Waveland Press.

Yore, L. D. (1991). Secondary science teachers' attitudes toward and beliefs about science reading and science textbooks. *Journal of Research in Science Teaching*, *28*, 55-72.

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